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(54) **HIGH-PRESSURE CONTAINMENT SLEEVE FOR NOZZLE ASSEMBLY AND FUEL INJECTOR USING SAME**

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F02M 47/02 (2006.01)
F02M 61/16 (2006.01)

(52) **U.S. Cl.**
CPC ***F02M 47/027*** (2013.01); ***F02M 61/168*** (2013.01)

(58) **Field of Classification Search**
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USPC 239/88, 96, 533.9–533.12, 239/533.1–533.3, 585.1
See application file for complete search history.

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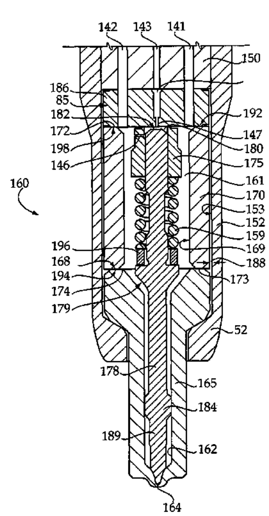
(57) **ABSTRACT**

A nozzle assembly for a fuel injector capable of withstanding high-pressures includes a nozzle chamber defined by a high-pressure containment sleeve, a tip component defining a nozzle outlet, and an injector stack component. A leakage path is defined between an injector body casing and an outer wall surface of the high-pressure containment sleeve and a needle valve member that opens and closes the nozzle outlet is out of contact with the high-pressure containment sleeve. The high-pressure containment sleeve has a hollow, cylindrical shape and has an inner wall exposed to fluid pressure inside the nozzle chamber that is free of stress concentrating surface features associated with heart shaped cavities in the prior art.

10 Claims, 2 Drawing Sheets



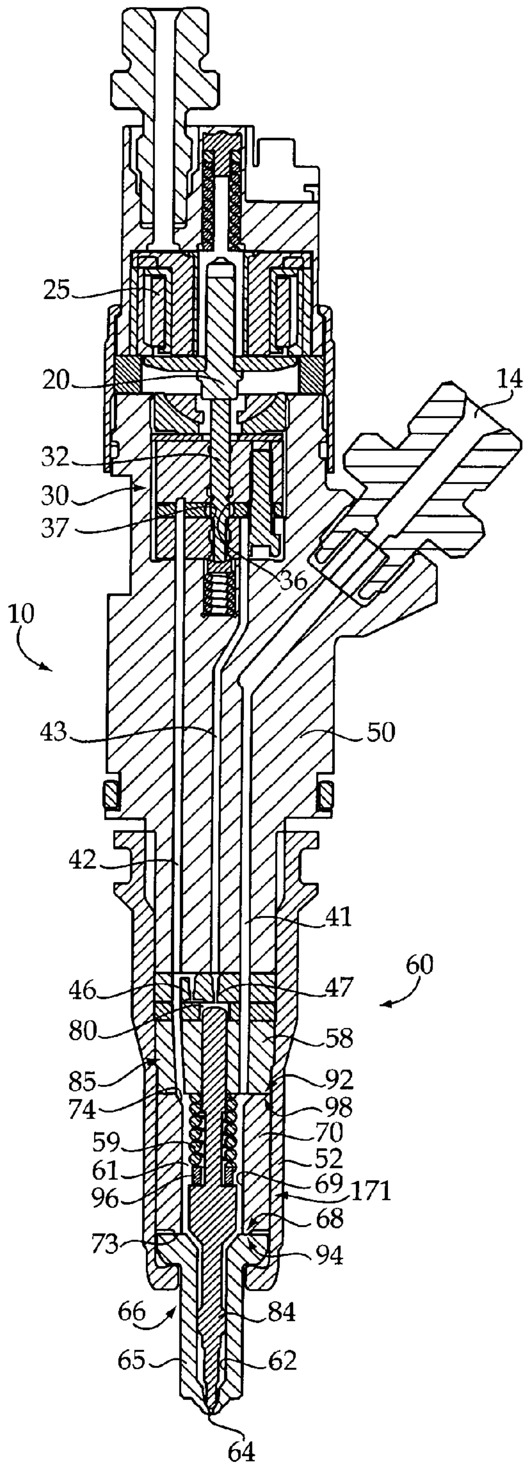


Figure 1

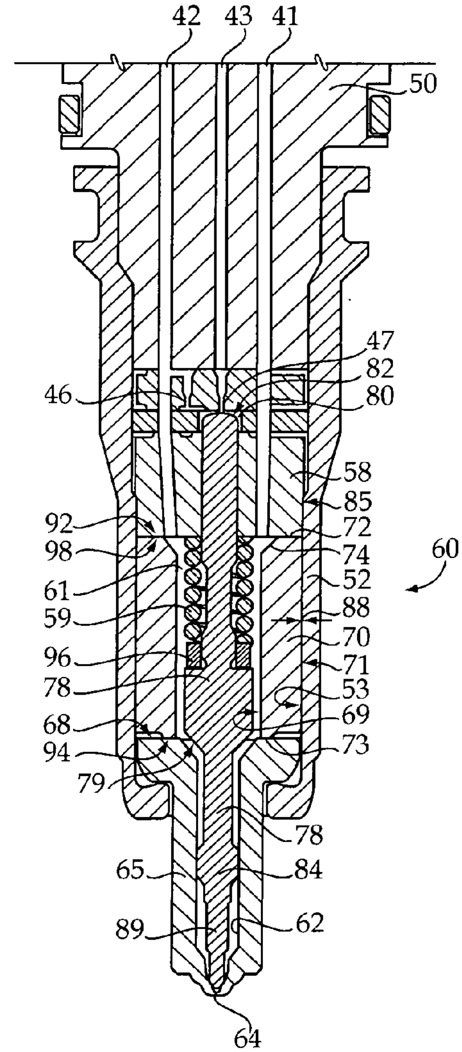


Figure 2

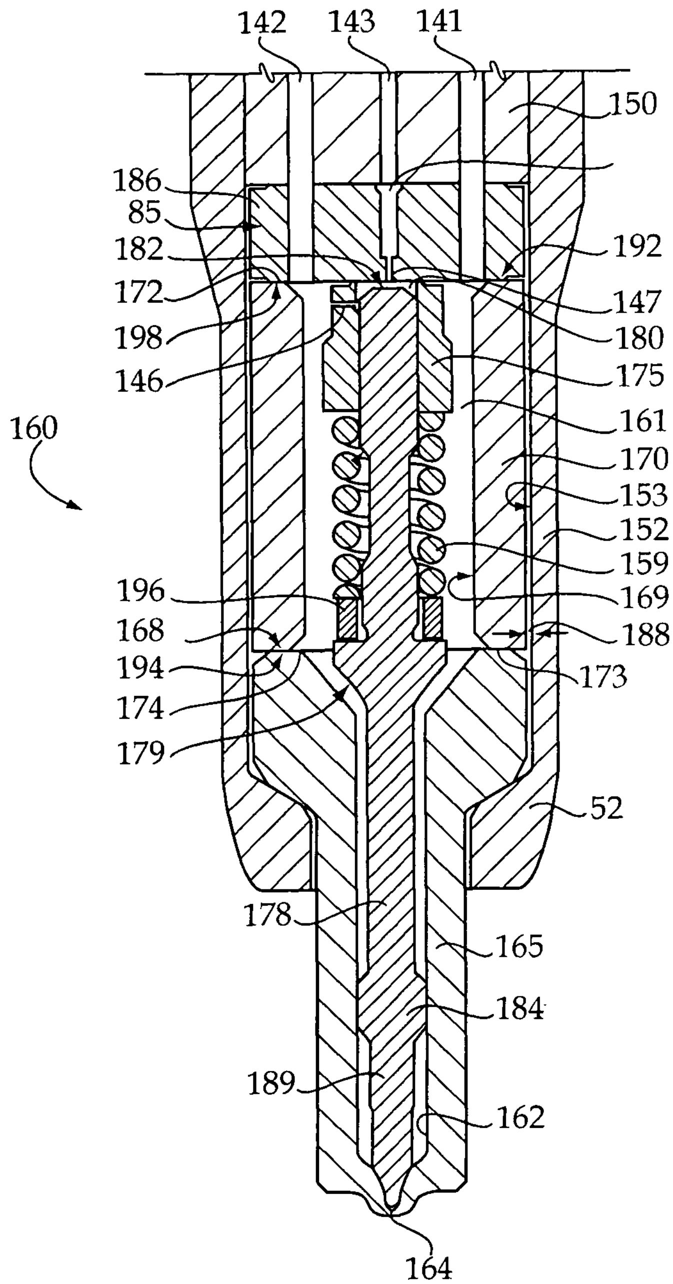

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Figure 3

HIGH-PRESSURE CONTAINMENT SLEEVE FOR NOZZLE ASSEMBLY AND FUEL INJECTOR USING SAME

TECHNICAL FIELD

The present disclosure relates generally to nozzle assemblies in fuel injectors, and in particular, to nozzle assemblies including a pressure containment system.

BACKGROUND

Manufacturers of fuel injectors are continuously trying to raise the injection pressure of fuel to reduce undesirable emissions as well as improve fuel efficiency in engines. However, due to geometrical limitations and spatial constraints in smaller fuel injectors, structural problems may prevent the fuel injectors from sustaining pressures above 200 MPa. Currently, the nozzle assembly of fuel injectors defines a heart shaped cavity formed in a metallic tip to contain the pressure inside the nozzle assembly.

U.S. Pat. No. 7,331,329 ('329 patent) discusses improving fuel efficiency by reducing static leakage by connecting a spring chamber to a common rail instead of to a low pressure vent. FIG. 4 of the '329 patent illustrates an embodiment of a nozzle assembly without the type of heart shaped cavity inside the fuel injector that is typical in the art.

The present disclosure is directed to overcoming one or more of the problems set forth above.

SUMMARY

In one aspect a nozzle assembly includes a tip component defining a nozzle outlet. A high-pressure containment sleeve is disposed within an injector body casing. The high-pressure containment sleeve and the tip component partially define a nozzle chamber. A needle valve member is movable between a first position that closes the nozzle outlet and a second position that opens the nozzle outlet. The needle valve member includes an opening hydraulic surface exposed to fluid pressure in the nozzle chamber. The needle valve member is out of contact with the high-pressure containment sleeve.

In another aspect, a fuel injector includes an injector body, which includes a tip component that defines a nozzle outlet and a high-pressure containment sleeve disposed within an injector body casing. The high-pressure containment sleeve and the tip component partially define a nozzle chamber. The fuel injector also includes a needle valve member that is disposed within the injector body and movable between a first position that closes the nozzle outlet and a second position that opens the nozzle outlet. The needle valve member includes an opening hydraulic surface exposed to fluid pressure in the nozzle chamber. The needle valve member also includes a closing hydraulic surface that is exposed to fluid pressure in a needle control chamber. The needle valve member is out of contact with the high-pressure containment sleeve, and a control valve assembly is fluidly connected to the needle control chamber.

In yet another aspect, a method of operating a fuel injector includes a step of forming a nozzle chamber within a high-pressure containment sleeve. The method also includes the step of containing pressure inside the nozzle chamber with a wall thickness of the high-pressure containment sleeve. The method also includes sealing the nozzle chamber by sizing annular sealing lands between the high-pressure containment sleeve and a tip component and an injector stack component, respectively, to have radial widths smaller than the wall thickness of the high-pressure containment sleeve. The method also includes exposing an opening hydraulic surface of a needle valve member to fluid pressure inside the nozzle chamber, and maintaining the high-pressure containment sleeve out of contact with the needle valve member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a front sectioned view of a fuel injector;

FIG. **2** shows an enlarged front sectioned view of a nozzle assembly of the fuel injector in FIG. **1**; and

FIG. **3** shows an enlarged sectioned view of a nozzle assembly of a fuel injector according to another embodiment of the present disclosure.

DETAILED DESCRIPTION

The present disclosure relates to a nozzle assembly of any fuel injector that incorporates a high-pressure containment sleeve that partially defines a nozzle chamber. In the past, nozzle assemblies included a heart shaped cavity, which was surrounded by a metallic wall of a tip component. As the pressures inside fuel injectors are increased to achieve better emissions and fuel efficiency, the metallic wall of the heart shaped cavity of the nozzle assemblies may form cracks and stress fractures. The heart shaped cavity may only become problematic in small injectors with inadequate wall thickness at higher pressures. Larger fuel injectors may not experience the formation of cracks and stress fractures in the walls of the heart shaped cavity because there is ample space inside the fuel injector to increase the wall thickness of the metallic wall that defines the heart shaped cavity. The present disclosure replaces the heart shaped cavity by introducing a high-pressure containment sleeve, which will allow smaller fuel injectors to sustain fuel pressures over 200 MPa without experiencing stress fractures. Further, the present disclosure is pertinent to all types of fuel injectors including common rail, hydraulic and cam actuated fuel injectors as well as fuel injectors of varying sizes. For the sake of simplicity, a common rail fuel injector is described. However, various types of fuel injectors incorporating the nozzle assembly described herein all fall within the scope of this disclosure. The present disclosure describes a nozzle assembly, which replaces a heart-shaped cavity design with a high-pressure containment sleeve.

Referring to FIGS. **1** and **2**, a fuel injector **10** includes an injector body **50** having an injector body casing **52**, a nozzle assembly **60**, a control valve assembly **30** and an armature assembly **20** that moves under the action of a solenoid coil **25**. The nozzle assembly **60** includes a high-pressure containment sleeve **70**, which is disposed within the injector body casing **53**, and is in sealed contact with an injector stack component **85** and a tip component **65**. The high-pressure containment sleeve **70**, the injector stack component **85** and the tip component **65** define a nozzle chamber **61**, in which a needle valve member **78** is movably positioned. In one embodiment, a nozzle spring **59** biases the needle valve member **78** to a closed position. A nozzle spring spacer **96** may set a preload on the nozzle spring **59**.

The high-pressure containment sleeve **70** has an outer wall surface **71**, an inner wall surface **69**, a top surface **92** and a bottom surface **94**. The high-pressure containment sleeve **70** has a hollow, cylindrical shape, which means the high-pressure containment sleeve **70** is cylindrical in shape and has a hollow interior bore through the top and bottom surfaces **92** and **94** of the high-pressure containment sleeve **70**. The high-pressure containment sleeve has a wall thickness defined by the difference between the radius of the outer wall surface **71** and the radius of the inner wall surface **69** of the high-pressure containment sleeve **70**. The wall thickness of the high-pressure containment sleeve **70** is designed to accommodate expected hoop stresses from expected pressure levels in the high-pressure containment sleeve **70**. Those skilled in the art appreciate that hoop stress may be the greatest towards the mid-section of the high-pressure containment sleeve **70**, therefore, the thickness of the high-pressure containment sleeve **70** is determined from the thickness at the mid-section of the high-pressure containment sleeve **70**. Although the thickness of the high-pressure containment sleeve **70** may vary throughout its length, it may be easier to manufacture a high-pressure containment sleeve **70** with a uniform thickness. In one embodiment, the high-pressure containment sleeve **70** has a uniform wall thickness along a majority of the length of the high-pressure containment sleeve **70**, which means that the wall thickness remains the same for more than half of the length of the high-pressure containment sleeve **70**.

The high-pressure containment sleeve **70** includes an upper sealing land **72** located on the top surface **92** of the high-pressure containment sleeve **70** and a lower sealing land **73** located on the bottom surface **94** of the high-pressure containment sleeve **70**. The upper and lower sealing lands **72** and **73** may be annular, and have a radial surface width smaller than the thickness of the wall of the high-pressure containment sleeve **70**. The term radial surface width is defined as the difference between the radius of an outer edge of the sealing land and the radius of an inner edge of the sealing land. Those skilled in the art may appreciate that by having the radial surface width of the sealing lands **72** and **73** smaller than the wall thickness of the high-pressure containment sleeve **70**, the clamping pressure acting on the sealing lands **72** and **73** will be greater, therefore, producing better sealing. The top surface **92** and the bottom surface **94** of the high-pressure containment sleeve **70** may have chamfers **74**, or some other surface contour, which also result in the sealing lands **72** and **73** having a smaller radial surface width compared to the wall thickness at the mid-section of the high-pressure containment sleeve **70**. The bottom surface **94** of the high-pressure containment sleeve **70** and a top surface **68** of the tip component **65** are in contact and form a seal to prevent fluid from leaking out of the nozzle chamber **61**.

The outer wall surface **71** of the high-pressure containment sleeve **70** is separated from the inner wall **53** of the injector body casing **52** by a space, which may be referred to as a leakage path **88**. The leakage path **88** runs along the inner wall **53** of the injector body casing **52** into a drain outlet port (not shown) of the fuel injector **10**.

In addition to the high-pressure containment sleeve **70**, the nozzle assembly **60** includes the tip component **65** that includes an outer wall **66**, a top surface **68**, a bottom end **67**, which defines a nozzle outlet **64**. A bore **62** is defined within the tip component **65** and runs from the top surface **68** of the tip component **65** towards the bottom end **67** of the tip component **65**, where it opens up into the nozzle outlet **64**. The tip component **65** is partially disposed within the injector body casing **52**, and the outer wall **66** of the tip component **65** may form a sealing contact **56** with the injector body casing **52**, preventing any fuel that enters into the leakage path **88** to escape from between the inner wall surface **53** of the injector body casing **52** and the outer surface **66** of the tip component **65**.

In the embodiment shown in FIGS. **1** and **2**, the injector stack component **85** may be a guide piece **58**. The nozzle chamber **61** is defined by the inner wall surface **69** of the high-pressure containment sleeve **70**, the top surface **68** of the tip component **65** and the guide piece **58**. In this embodiment, the guide piece **58** is the injector stack component **85** that may guide the needle valve member **78** while it is moving between an open position and a closed position. At all times the needle valve member remains out of contact with, or surrounded by, the high-pressure containment sleeve **70** as shown in FIGS. **1** and **2**. A nozzle spring **59** biases the needle valve member **78** to the closed position. The needle valve member **78** has an opening hydraulic surface **79** exposed to fluid pressure inside the nozzle chamber **61** and a closing hydraulic surface **82** exposed to pressure in a needle control chamber **80**, which is disposed within the nozzle assembly **60**. The needle valve member **78** is partially disposed inside the bore **62** of the tip component **65** and slidably moves within the bore **62**. The needle valve member **78** may be made from a plurality of pieces, but the illustrated embodiment shows a unitary construction that includes a lower valve member **89** and a guide segment **84**. The guide segment **84** may be located on the needle valve member **78** and may guide the needle valve member **78** along the bore reducing the risk of misaligning the needle valve member **78** with the bore **62** of the tip component **65**, and therefore allowing the nozzle outlet **64** to open and close more accurately.

The nozzle chamber **61** is fluidly connected to a rail inlet port **14** of the fuel injector **10** via a fuel supply passage **41** that opens into nozzle chamber **61** at a location offset from a centerline of the high pressure containment sleeve **70** as shown in FIGS. **1** and **2**. The nozzle chamber **61** allows high-pressure fuel entering into the rail inlet port **14** to enter through the fuel supply passage **41** into the nozzle chamber **61**. A pressure communication passage **42** fluidly connects the nozzle chamber **61** to the control valve assembly **30**. The pressure communication passage **42** is also fluidly connected to the needle control chamber **80** via a first flow restrictor **46** that extends between the pressure communication passage **42** and the needle control chamber **80**.

The control valve assembly **30** includes a control valve member **31** that moves between a lower valve seat **37** and an upper valve seat **36**. The control valve assembly **30** may be electrically actuated by a solenoid coil **25**, which controls the movement of an armature assembly **20** between a first armature position and a second armature position. The control valve assembly **30** is fluidly connected to the needle control chamber **80** via a valve supply passage **43** and a second flow restrictor **47**. The second flow restrictor **47** is fluidly connected to the needle control chamber **80**, and the flow area of the second flow restrictor **47** may be greater than the flow area of the first flow restrictor **46**.

The control valve assembly **30** may fluidly connect the valve supply passage **43** to a low pressure drain or to the pressure communication passage **42**, depending on whether the control valve member **31** is seated at the upper valve seat **36** or lower valve seat **37**, respectively.

Typically, the nozzle chamber **61** and the pressure communication passage **42** are always at high-pressure as there is an unobstructed fluid connection with the common rail (not shown) through the rail inlet port **14**. However, the pressure inside the needle control chamber **80** varies between high-pressure and low-pressure. When the solenoid coil **25** is de-energized, the armature assembly **20** is in the first armature position and the control valve member **32** is seated at the lower valve seat **37**. The pressure communication passage **42** is fluidly connected to the valve supply passage **43**, which in turn is connected to the needle control chamber **80** via the second flow restrictor **47**. The pressure communication passage **42** is continuously supplying high-pressure fuel to the needle control chamber **80** via the first flow restrictor **46** and therefore, the needle control chamber **80** is exposed to high-pressure fuel when the solenoid coil **25** is de-energized. When the solenoid coil **25** is energized, the armature assembly **20** moves to the second armature position and the control valve member **32** is seated at the upper valve seat **36**. The fluid connection between the pressure communication passage **42** and the valve supply passage is now blocked. Instead, the valve supply passage **43** is now fluidly connected to a low-pressure drain (not shown), allowing fuel from the needle control chamber **80** to flow to the low-pressure drain. As the second flow restrictor **47** has a larger flow area than the first flow restrictor **46**, more fuel leaves the needle control chamber **80** than the amount of fuel entering, hence reducing the pressure inside the needle control chamber **80**.

Referring to FIG. **3**, another embodiment of a nozzle assembly **160** is shown. Numbers that appear in FIG. **3** that similar to those in FIGS. **1** and **2**, such as **72** and **172** or **74** and **174** may be used to show that they represent similar items.

Referring generally to FIGS. **1**, **2** and **3**, those skilled in the art may appreciate that a nozzle assembly may come in various shapes and forms. FIGS. **1** and **2** show one embodiment of the nozzle assembly **60**, where there is no control orifice component **186** and the needle control chamber **80** is isolated from the nozzle chamber **61** by an injector stack component **85**. FIG. **3** shows a nozzle assembly **160** of another embodiment of a fuel injector **100** where the needle control chamber **180** is partially defined by a control orifice component **186** and a floating check guide **175**. The nozzle assembly **160** includes a high-pressure containment sleeve **170**, which is disposed within an injector body casing **153**, and is in sealed contact with an injector stack component **185** and a tip component **165**. The high-pressure containment sleeve **170** may be a check lift sleeve **170**. The check lift sleeve **170**, the injector stack component **85** and the tip component **165** define a nozzle chamber **161**, in which a needle valve member **178** is movably positioned. In one embodiment, a nozzle spring **159** biases the needle valve member **178** to a closed position. A nozzle spring spacer **196** may set a preload on the nozzle spring **159**.

The check lift sleeve **170** has an outer wall surface **171**, an inner wall surface **169**, a top surface **192** and a bottom surface **194**. The check lift sleeve **170** has a hollow, cylindrical shape, which means the check lift sleeve **170** is cylindrical in shape and has a hollow interior bore through the top and bottom surfaces **192** and **94** of the check lift sleeve **170**. The check lift sleeve **170** has a wall thickness defined by the difference between the radius of the outer wall surface **171** and the radius of the inner wall surface **169** of the check lift sleeve **170**. The wall thickness of the check lift sleeve **170** is designed to accommodate expected hoop stresses from expected pressure levels in the check lift sleeve **170**. Those skilled in the art appreciate that hoop stress may be the greatest towards the mid-section of the check lift sleeve **170**, therefore, the thickness of the check lift sleeve **170** is determined from the thickness at the mid-section of the check lift sleeve **170**. Although the thickness of the check lift sleeve **170** may vary throughout its length, it may be easier to manufacture a check lift sleeve **170** with a uniform thickness. In one embodiment, the check lift sleeve **170** has a uniform wall thickness along a majority of the length of the check lift sleeve **170**, which means that the wall thickness remains the same for more than half of the length of the check lift sleeve **170**.

In one embodiment, the check lift sleeve **170** includes an upper sealing land **172** located on the top surface **192** of the check lift sleeve **170** and a lower sealing land **173** located on the bottom surface **194** of the check lift sleeve **170**. The upper and lower sealing lands **172** and **173** may be annular, and have

a radial surface width smaller than the thickness of the wall of the check lift sleeve **170**. The term radial surface width is defined as the difference between the radius of an outer edge of the sealing land and the radius of an inner edge of the sealing land. Those skilled in the art may appreciate that by having the radial surface width of the sealing lands **172** and **173** smaller than the wall thickness of the check lift sleeve **170**, the clamping pressure acting on the sealing lands **172** and **173** will be greater, therefore, producing better sealing. In one embodiment of the disclosure, the top surface **192** and the bottom surface **194** of the check lift sleeve **170** may have chamfers **174**, which also result in the sealing lands **172** and **173** having a smaller radial surface width compared to the wall thickness of the check lift sleeve **170** at the mid-section of the check lift sleeve **70**. The bottom surface **194** of the check lift sleeve **170** and a top surface **168** of the tip component **165** are in contact and form a seal to prevent fluid from leaking out of the nozzle chamber **161**.

The outer wall surface **171** of the check lift sleeve **170** is separated from the inner wall **153** of the injector body casing **152** by a space. The space between the outer wall surface **171** of the check lift sleeve **170** and the inner wall **153** of the injector body casing **152** defines a leakage path **188**. The leakage path **188** runs along the inner wall **153** of the injector body casing **152** into a drain outlet port (not shown) of the fuel injector **100**.

In addition to the check lift sleeve **170**, the nozzle assembly **160** includes the tip component **165** that includes an outer wall **166**, a top surface **168**, a bottom end **167**, which defines a nozzle outlet **164**. A bore **162** is defined within the tip component **165** and runs from the top surface **168** of the tip component **165** towards the bottom end **167** of the tip component **165**, where it opens up into the nozzle outlet **164**. The tip component **165** is partially disposed within the injector body casing **152**, and the outer wall **166** of the tip component **165** may form a sealing contact **156** with the injector body casing **152**, preventing any fuel that enters into the leakage path **188** to escape from between the inner wall surface **153** of the injector body casing **152** and the outer surface **166** of the tip component **165**.

In the embodiment shown in FIG. **3**, the injector stack component **85** is a control orifice component **186**. The nozzle chamber **161** is defined by the inner wall surface **169** of the check lift sleeve **170**, the top surface **168** of the tip component **165** and a bottom surface **198** of the control orifice component **186**. In this embodiment, a floating check guide **175** is biased into contact with the bottom surface **198** of the control orifice component **186** by the nozzle spring **159**. The floating check guide **175** may guide the needle valve member **178** while it is moving between an open position and a closed position. The needle valve member **178** always remains out of contact with, but surrounded by, the check lift sleeve **170** as shown in FIG. **3**. A nozzle spring **159** also biases the needle valve member **178** to the closed position. The needle valve member **178** has an opening hydraulic surface **179** exposed to fluid pressure inside the nozzle chamber **161** and a closing hydraulic surface **182** exposed to a needle control chamber **180**, which is disposed within the nozzle assembly **160**. The needle valve member **178** is partially disposed inside the bore **162** of the tip component **165** and slidably moves within the bore **162**. The needle valve member **178** may be made from a plurality of pieces, including a lower valve member **189**, which may be in contact with a guide segment **184**. The guide segment **184** may be located on the needle valve member **178** and may guide the needle valve member **78** along the bore reducing the risk of misaligning the needle valve member **178** with the bore **162** of the tip component **165**, and therefore allowing the nozzle outlet **164** to open and close more accurately.

This nozzle assembly **160** is a part of a fuel injector **100** (partially shown in FIG. **3**) contains many similar features to the nozzle assembly **60** shown in FIGS. **1** and **2**, but differs slightly from the nozzle assembly **60** shown in FIGS. **1** and **2** in that the nozzle chamber **161** is defined by the inner wall surface **169** of the check lift sleeve **170**, the top surface **168** of the tip component **165** and the bottom surface **198** of the orifice control component **186**. Further, the floating check guide **175** defines a first flow restrictor **146** and the floating check guide **175** along with the needle valve member **178** and the bottom surface **198** of the orifice control component **186** define a needle control chamber **180**. A nozzle spring spacer **196** may be used to set the preload of the nozzle spring **159**. In one embodiment, the needle control chamber **180** and the nozzle chamber **161** are fluidly connected through a first flow restrictor **146**, which is defined within the floating check guide **75**. In contrast to the embodiment shown in FIG. **3**, the embodiment shown in FIG. **2** shows the first flow restrictor **46** fluidly connects the needle control chamber **80** to the pressure communication passage **42**.

It may further be appreciated by those skilled in the art that this disclosure relates to a nozzle assembly **60** that may be implemented into a wide variety of fuel injectors. The disclosure herein may pertain to certain types of fuel injectors, such as, common rail fuel injectors. However, the scope of the disclosure is not intended to be limited to the embodiments described herein, but rather to all embodiments that fall within the spirit of this disclosure.

Industrial Applicability

The present disclosure finds potential application in fuel injectors and fuel systems in any engine or machine. The present disclosure has a general applicability in fuel injectors used in smaller engines and a particular applicability in smaller sized fuel injectors operating at higher pressures, such as above 200 MPa.

The nozzle assemblies **60** and **160** described in this disclosure may be used to operate any fuel injector. The nozzle assemblies **60** and **160** described in this disclosure may be suitable for common rail fuel injectors that want to achieve higher fuel injection pressures. Those skilled in the art may appreciate the various ways of controlling the flow of fuel through the nozzle outlet via a solenoid actuated valve assembly. The present disclosure describes the sequence of an injection event inside an electrically actuated common rail fuel injector **10**, **100** including the nozzle assembly **60**, **160** shown in FIGS. **1**, **2** and **3**. Those skilled in the art may acknowledge that the disclosure describing the sequence of an injection event is not limited only to the embodiments disclosed within but to all other embodiments that fall within the spirit of the disclosure.

An injection event begins from the time the electrical actuator **25** is energized, and ends when the electrical actuator **25** is de-energized. Prior to an injection event, the electrical actuator **25** is de-energized, and the armature assembly **20** is in the first armature position. The control valve member **31** is seated at the lower valve seat **37**, thereby allowing the valve supply passage **43**, **143** to be fluidly connected to the pressure communication passage **42**, **142**. The control valve assembly **30** has a first configuration when the needle control chamber **80**, **180** is connected to a low-pressure passage and has a second configuration when the needle control chamber **80**, **180** is blocked from the low-pressure passage. During this period, fuel enters the fuel injector **10** through the rail inlet port **14** and enters the nozzle chamber **61**, **161** through the fuel supply passage **41**, **141**. The nozzle chamber **61**, **161** contains high-pressure fuel, which is exerted on the opening hydraulic surface **79**. **179** of the needle valve member **78**, **178**. In the embodiment shown in FIG. **2**, the high-pressure fuel flows through the pressure communication passage **42** and into the needle control chamber **80** through the first flow restrictor **46**. However, in the embodiment of FIG. **3**, the high-pressure fuel flows through the nozzle chamber **161** into the needle control chamber **186** via the first flow restrictor **146**. When the control valve member **31** is in the lower valve seat **37**, fuel from the pressure communication passage **42**, **142** may move into the valve supply passage **43**, **143** and into the needle control chamber **80**, **180** also via the second flow restrictor **47**, **147**. The control valve **30** is in the first configuration when the needle control chamber **80**, **180** is fluidly blocked from the low-pressure drain. Because there is high-pressure fuel inside the needle control chamber **80**, **180** the closing hydraulic surface **82**, **182** is also exposed to high-pressure. This pressure combined with the preload of the nozzle spring **59**, **159** holds the needle valve member **78**, **178** in the closed position, thereby not allowing any fuel from the nozzle chamber **61**, **161** to leak out of the nozzle outlet **64**, **164**. Fuel inside the nozzle chamber **61**, **161** is at high-pressure and the upper sealing lands **72**, **172** and lower sealing lands **73**, **172** of the high-pressure containment sleeve **70**, **170** prevent the fuel from leaking into the leakage path **88**, **188**. Leakage that may occur from the nozzle chamber **61**, **161** to the leakage path **88**, **188** may flow to the drain port because it is at a lower pressure.

As the electrical actuator **25** is energized, the armature assembly **20** moves from the first armature position to the second armature position. The control valve member **31** also moves from the lower valve seat **37** to the upper valve seat **36**, where it remains until the actuator **25** is de-energized. Fuel from the valve supply passage **43**, **143** may flow through the lower valve seat **37** into a low-pressure drain (not shown) instead of through the upper valve seat **36** to the pressure communication passage **42**, **142**. Fuel may continue to move into the needle control chamber **80**, **180** from the first flow restrictor **46**, **146**, but because the valve supply passage **43** is now connected to the low pressure drain, high-pressure fuel moves from the needle control chamber **80**, **180** to the drain via the second flow restrictor **47**, **147** and the valve supply passage **43**, **143** because the second flow restrictor **47**, **147** has a larger flow area than the first flow restrictor **46**. The needle control chamber **80**, **180** now may have a lower pressure and subsequently, lower pressure is acting on the closing hydraulic surface **82**, **182** of the needle valve member **78**, **178**.

When the actuator **25** is energized and the needle control chamber **80**, **180** has lower pressure, the force acting upon the opening hydraulic surface **79**, **179** of the needle valve member **78**, **178** exceeds the preload of the nozzle spring **59**, **159** and the force acting upon the closing hydraulic surface **82**, **182**. Relieving the pressure acting on the closing hydraulic surface **82**, **182** of the needle valve member **78**, **178** inside the needle control chamber **80**, **180** allows the needle valve member **78**, **178** to move to the open position, allowing the nozzle outlet **64**, **64** to open. In one embodiment, the closing hydraulic surface **82**, **182** of the needle valve member **78**, **178** does not touch the injector stack component **85**, **185** because the interaction between the first and second flow restrictors **46**, **146** and **47**, **147** hydraulically stops the needle valve member **78**, **178** before it hits the injector stack component **85**, **185**. In the nozzle assembly **60** shown in FIG. **2**, the injector stack component **85** is the guide piece **58**, while in the nozzle assembly in FIG. **3**, the injector stack component **85** is the control orifice component **186**. Fuel from the nozzle chamber **61**, **161** flows through the nozzle outlet **64**, **164** until the nozzle outlet **64**, **164** is closed again. When the actuator **25** is energized, the control valve **30** is in the second configuration fluidly connecting the needle control chamber **80**, **180** to the low-pressure drain.

The needle valve member **78**, **178** is guided via an interaction between the needle valve member **78**, **178** and the tip component **65**, **165**. In one embodiment, the guide segment **84**, **184** of the needle valve member **78**, **178** guides the needle valve member **78**, **178** along the bore **62**, **162** of the tip component **65**, **165**, and the guide segment **84**, **184** may prevent the needle valve member **78**, **178** from being misaligned with the bore **62**, **162** of the tip component **65**, **165**. Those skilled in the art will understand the importance of maintaining the alignment of the needle valve member **78**, **178** with respect to the bore **62**, **162** of the tip component **65**, **165** and the nozzle assembly **60**, **160** because maintaining alignment between the bore **62**, **162** and the needle valve member **78**, **178** will reduce wear and tear caused by rubbing the needle valve member **78**, **178** against the bore **62**, **162** as well as improve the accuracy at which the nozzle outlet **64**, **164** is opened and closed.

In order to end the injection event, the nozzle outlet **64**, **164** is closed by de-energizing the actuator **25**. When the actuator **25** is de-energized, the armature assembly **20** moves from the second armature position to the first armature position, consequently moving the control valve member **31** from the upper valve seat **36** back to the lower valve seat **37**. Once the control valve member **32** is at the lower valve seat **37**, the fluid connection between valve supply passage **43**, **143** and the low pressure drain is now disconnected. Instead, the valve supply passage **43**, **143** is once again fluidly connected to the pressure communication passage **42**, **142** allowing high-pressure fuel from the pressure communication passage **42**, **142** to flow to the valve supply passage **43**, **143**. In the nozzle assembly **60** shown in FIG. **2**, fuel from the pressure communication passage **42** fills the needle control chamber **80** with high-pressure fuel since high-pressure fuel is entering the needle control chamber **80** through both the first flow restrictor **46** and second flow restrictor **47**. In the nozzle assembly **160** shown in FIG. **3**, fuel from the nozzle chamber **161** enters the needle control chamber **180** via the first flow restrictor **146** and fuel from the pressure communication passage **142** enters the needle control chamber **180** via the second flow restrictor **147**. High pressure inside the needle control chamber **80**, **180** acts on the closing hydraulic surface **82**, **182** of the needle valve member **78**, **178** causing the needle valve member **78**, **178** to move to its closed position from the open position. Thereby, the nozzle outlet **64**, **164** is closed and the injection event is terminated.

Those skilled in the art will also appreciate that the pressure inside the nozzle chamber **61**, **161** is dependent upon the rail pressure. Further, because there is an unobstructed fluid connection between the rail inlet port **14** and the nozzle chamber **61**, **161** and the nozzle outlet's **64**, **164** flow area is smaller than the flow area of the fuel supply passage **41**, **141**, the nozzle chamber **61**, **161** maintains high-pressure both during and between injection events.

Also, the sealing lands **72**, **172** and **73**, **173** of the high-pressure containment sleeve **70**, **170** may be annular and may be smaller in width than the wall thickness of the high-pressure containment sleeve **70**, **170**. The sealing lands **72**, **172** and **73**, **173** prevent the high-pressure fuel from leaking into the leakage path **88**, **188**. Because the components of the fuel injector **10**, **100** are clamped together to contain the fuel pressure, the forces are exerted on the respective components of the fuel injector **10**, **100**. By reducing the surface area of the sealing lands of the components, the pressure is increased on the surface of the sealing land allowing for better sealing capabilities.

Referring to FIG. **3**, a nozzle assembly **160** of a fuel injector **100** according to another embodiment of the present disclosure is shown. The nozzle assembly **160** is similar to the nozzle assembly **60** shown in FIGS. **1** and **2**, except for a few differences in structure. The nozzle assembly **160** includes a floating check guide **175**, which is in contact with the needle valve member **178**, and the bottom surface of the injector stack component **85**. In this embodiment, the control orifice component **186** is one embodiment of the injector stack component **85**. The floating check guide **175** is biased to be in flat seat sealing contact with the control orifice component **186** via the nozzle spring **159**.

The floating check guide **175** defines the first flow restrictor **146**, which extends between the nozzle chamber **161** and the needle control chamber **180** and thereby maintains an unobstructed fluid connection between the nozzle chamber **61** and the needle control chamber **80** during and between injection events. The second flow restrictor **182** is defined within the control orifice component **186** and extends between the needle control chamber **186** and the valve supply passage **143**. Similar to the embodiment shown in FIGS. **1** and **2**, the nozzle assembly **160** hydraulically stops the needle valve member after moving the needle valve member from a closed position to an open position. The first flow restrictor **146** fluidly connects the nozzle chamber **61** to the needle control chamber **80**, there will always be fluid inside the needle control chamber and therefore, the needle valve member will always have some fluid pressure acting on the closing hydraulic surface. The needle valve member **78** stops when the pressure acting on the closing hydraulic surface **82** and the preload of the spring **59** equal the pressure acting on the opening hydraulic surface **79** of the needle valve member **78** in the nozzle chamber **61**.

The nozzle assembly **160** also differs from the nozzle assembly **60** shown in FIGS. **1** and **2** in that the needle control chamber **182** is defined by the floating check guide **175**, the control orifice component **186** and the needle valve member **178**. The operation of the fuel injector **100** however remains similar to the operation of the fuel injector **10** described with reference to the nozzle assembly **60** shown in FIGS. **1** and **2**.

The present disclosure improves a fuel injector's ability to withstand higher injection pressures. By using a high-pressure containment sleeve, with adequate wall thickness and free from stress concentrating surface features, such as those associated with the heart shaped cavity of the prior art, smaller fuel injectors may withstand higher pressures without forming stress fractures. The ease in manufacturing the high-pressure containment sleeve also reduces the manufacturing costs of producing these fuel injectors, as machining a heart shaped cavity surrounded by metal may be more costly. Further, designing the high-pressure containment sleeves with annular sealing lands may provide for a better seal capable of withstanding these higher pressures for a longer injector life.

It should be understood that the above description is intended for illustrative purposes only, and is not intended to limit the scope of the present disclosure in any way. Thus, those skilled in the art will appreciate that other aspects of the disclosure can be obtained from a study of the drawings, the disclosure, and the appended claims.

What is claimed is:

1. A nozzle assembly comprising:
a tip component defining a nozzle outlet;
a high-pressure containment sleeve having a centerline and being disposed within an injector body casing;
the high-pressure containment sleeve and the tip component partially defining a nozzle chamber; a needle valve member movable between a first position that closes the nozzle outlet and a second position that opens the nozzle outlet;
the needle valve member including an opening hydraulic surface exposed to fluid pressure in the nozzle chamber;
the needle valve member is out of contact with, but surrounded by, the high-pressure containment sleeve;
an injector stack component that defines a segment of a fuel supply passage and a portion of the nozzle chamber; and the injector stack component also defines a pressure communication passage that terminates at a portion of the nozzle chamber surrounded by the high-pressure containment sleeve, wherein the segment of the fuel supply passage opens into the nozzle chamber offset from the centerline; wherein the high-pressure containment sleeve has a wall thickness at a middle section;
the high-pressure containment sleeve includes an annular sealing land having a radial surface width smaller than the wall thickness;
wherein the sealing land is in contact with the tip component.

2. The nozzle assembly of claim **1**, wherein the high-pressure containment sleeve has a hollow, cylindrical shape.

3. The nozzle assembly of claim **1**, further includes a needle control chamber partially defined by one needle valve member;
the needle valve member having a closing hydraulic surface exposed to pressure in the needle control chamber.

4. The nozzle assembly of claim **1**, wherein the high-pressure containment sleeve has a uniform wall thickness over a majority of a length of the high-pressure containment sleeve.

5. The nozzle assembly of claim **1**, wherein:
the high-pressure containment sleeve is hollow and has a uniform wall thickness over a majority of a length of the high-pressure containment sleeve; and
the high-pressure containment sleeve includes a second annular sealing land having a radial surface width smaller than the uniform wall thickness, wherein the second sealing land is in contact with the injector stack component.

6. A fuel injector comprising:
an injector body including:
a tip component defining a nozzle outlet;
a high-pressure containment sleeve disposed within an injector body casing;
the high-pressure containment sleeve and the tip component partially defining a nozzle chamber;
a needle valve member disposed within the injector body, movable between a first position that closes the nozzle outlet and a second position that opens the nozzle outlet;
the needle valve member including an opening hydraulic surface exposed to fluid pressure in the nozzle chamber and a closing hydraulic surface exposed to fluid pressure in a needle control chamber;
the needle valve member is out of contact with, but surrounded by, the high-pressure containment sleeve;
a control valve assembly fluidly connected to the needle control chamber;
an electrical actuator operably coupled to the control valve assembly;
an injector stack component that defines a segment of a fuel supply passage and a portion of the nozzle chamber and the injector stack component also defines a pressure communication passage that terminates at a portion of the nozzle chamber surrounded by the high-pressure containment sleeve wherein the segment of the fuel supply passage opens into the nozzle chamber offset from a centerline of the nozzle chamber;
a floating check guide disposed in the nozzle chamber;
the floating check guide partially defines the needle control chamber; and
the float check guide is out of contact with the high-pressure containment sleeve.

7. The nozzle assembly of claim **6**, wherein the high-pressure containment sleeve has a wall thickness at a middle section;
the high-pressure containment sleeve includes an annular sealing land having a radial surface width smaller than the wall thickness; wherein
the sealing land is in contact with the tip component.

8. The nozzle assembly of claim **7**, wherein the needle control chamber is partially defined by one end of the needle valve member.

9. The nozzle assembly of claim **8**, wherein the high-pressure containment sleeve has a uniform wall thickness over a majority of a length of the high-pressure containment sleeve.

10. A fuel injector comprising:
an injector body including:
a tip component defining a nozzle outlet;
a high-pressure containment sleeve disposed within an injector body casing;
the high-pressure containment sleeve and the tip component partially defining a nozzle chamber;
a needle valve member disposed within the injector body, movable between a first position that closes the nozzle outlet and a second position that opens the nozzle outlet,
the needle valve member including an opening hydraulic surface exposed to fluid pressure in the nozzle chamber and a closing hydraulic surface exposed to fluid pressure in a needle control chamber;
the needle valve member is out of contact with, but surrounded by, the high-pressure containment sleeve;
a control valve assembly fluidly connected to the needle control chamber;
an electrical actuator operably coupled to the control valve assembly;
an injector stack component that defines a segment of a fuel supply passage and a portion of the nozzle chamber and the injector stack component also defines a pressure communication passage that terminates at a portion of the nozzle chamber surrounded by the high-pressure containment sleeve wherein the segment of the fuel supply passage opens into the nozzle chamber offset from a centerline of the nozzle chamber;
a floating check guide disposed in the nozzle chamber;
the floating check guide partially defines the needle control chamber; and
the floating check guide is out of contact with the high-pressure containment sleeve,
wherein the control valve assembly having a first configuration wherein the needle control chamber is fluidy connected to a low pressure passage;

the control valve assembly having a second configuration wherein the needle control chamber is blocked from the low pressure passage; and

the electrical actuator is a solenoid actuator operably coupled to move the control valve assembly from the second configuration to the first configuration when energized.

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